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Miller et al.

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(54) EXERCISE DEVICE LIMB INTERFACE

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A63B 24/00	(2006.01)
A63B 21/005	(2006.01)

(52) **U.S. Cl.**

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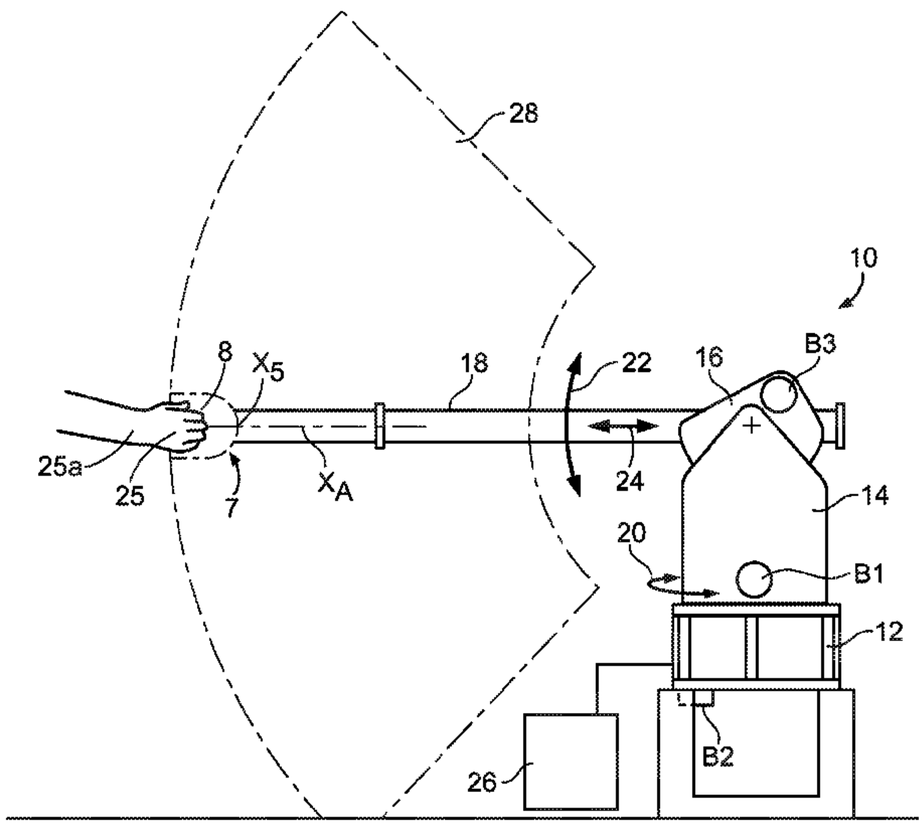
(57) **ABSTRACT**

A limb interface device for an exercise apparatus includes a handle member within an inner frame member rotatable about a first axis with a first joint, for gripping by a user. At least one outer support member supports the inner frame member. The inner frame member is rotatable about a second axis orthogonal to the first axis with a second joint. An outer arc member supports the at least one support member. The at least one support member is rotatable about a third axis orthogonal to the second axis with a third joint. An arm member supports the outer arc member. The outer arc member can rotate about a fourth axis that is orthogonal to the third axis with a fourth joint. The arm member can also be rotatable about a fifth axis that is longitudinal to the arm member and orthogonal to the fourth axis with a fifth joint.

20 Claims, 6 Drawing Sheets



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CPC ***A63B 21/4049*** (2015.10); ***A63B 24/0087*** (2013.01); *A63B 21/0056* (2013.01); *A63B 21/4017* (2015.10); *A63B 21/4019* (2015.10); *A63B 21/4021* (2015.10)

(58) **Field of Classification Search**
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See application file for complete search history.

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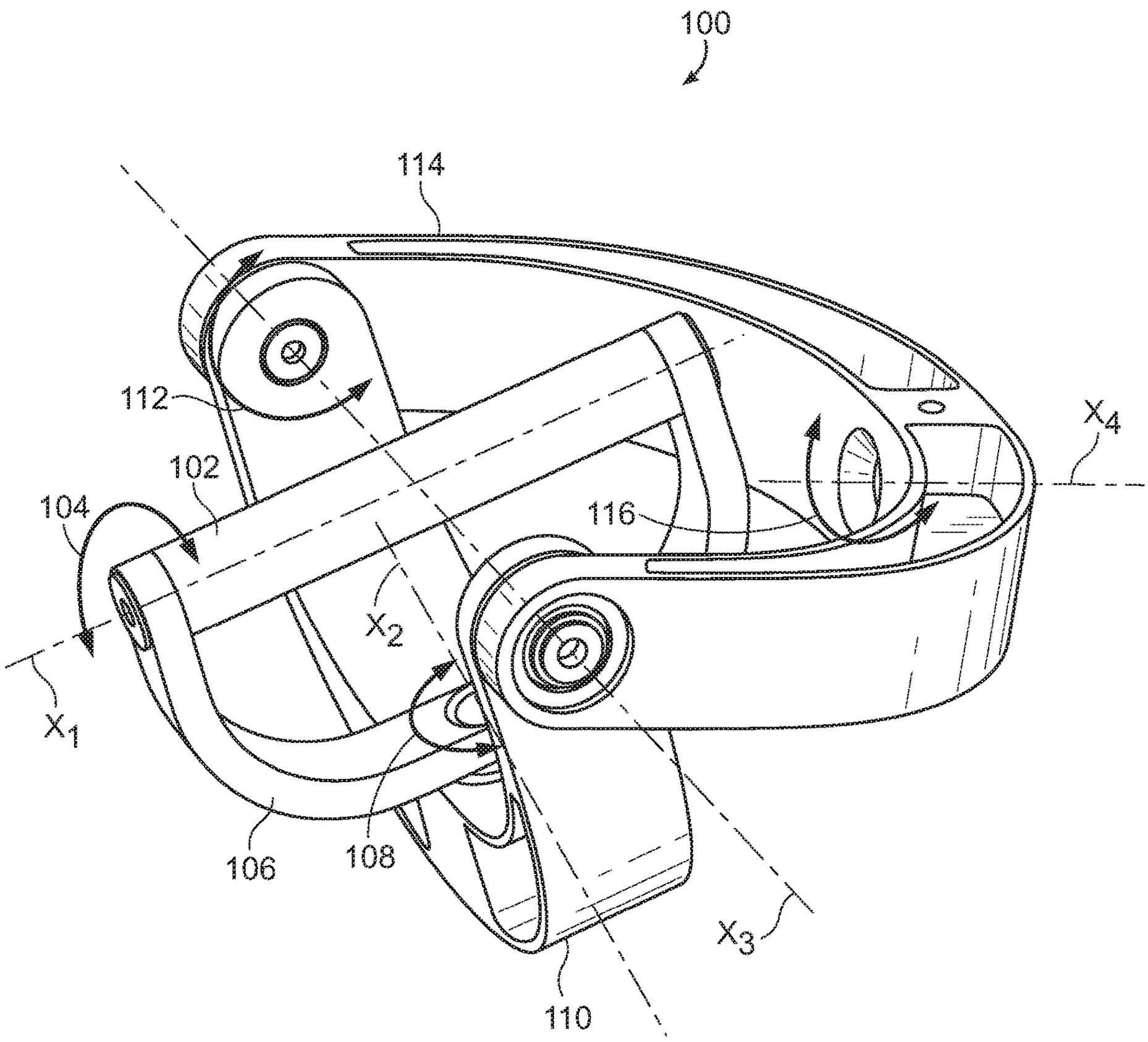


FIG. 1
PRIOR ART

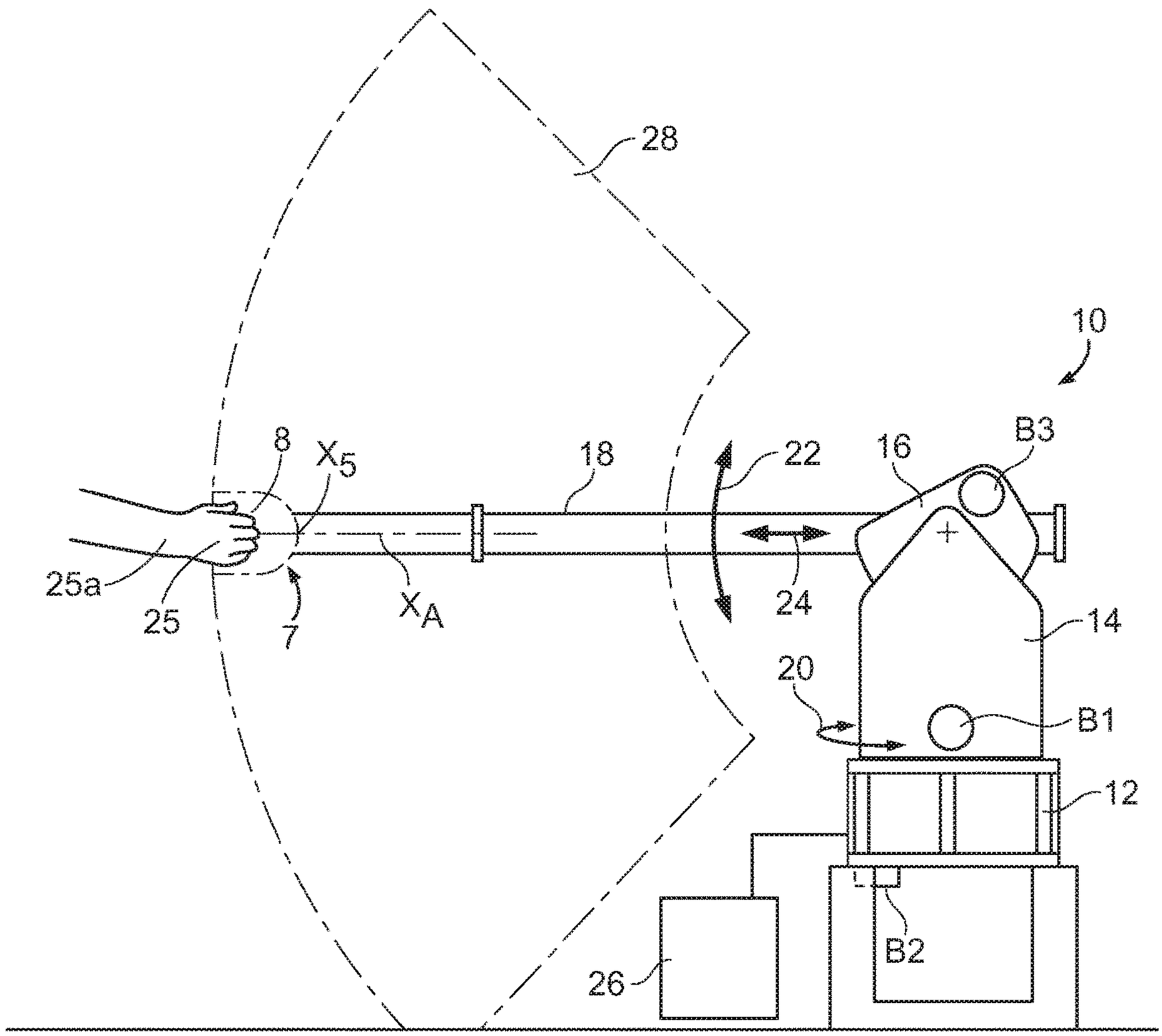
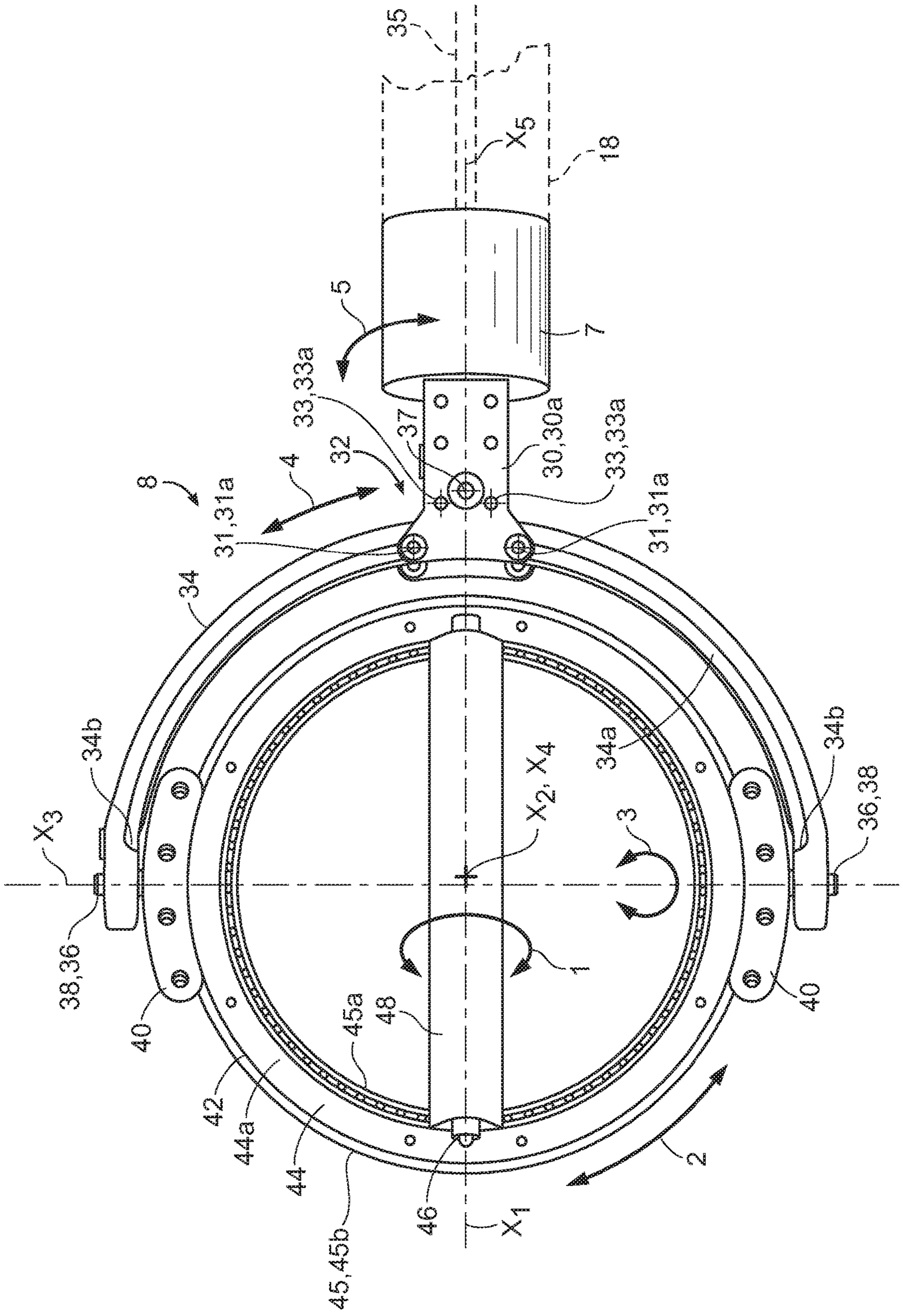


FIG. 2


35
18
X_5
5
7
33,33a
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4
32
8
31,31a
34
34b
X_3
6
38,36
40
42
44a
44
45,45b
46
X_1
48
45a
X_2, X_4
34a
3
1
2
36,38

FIG. 3

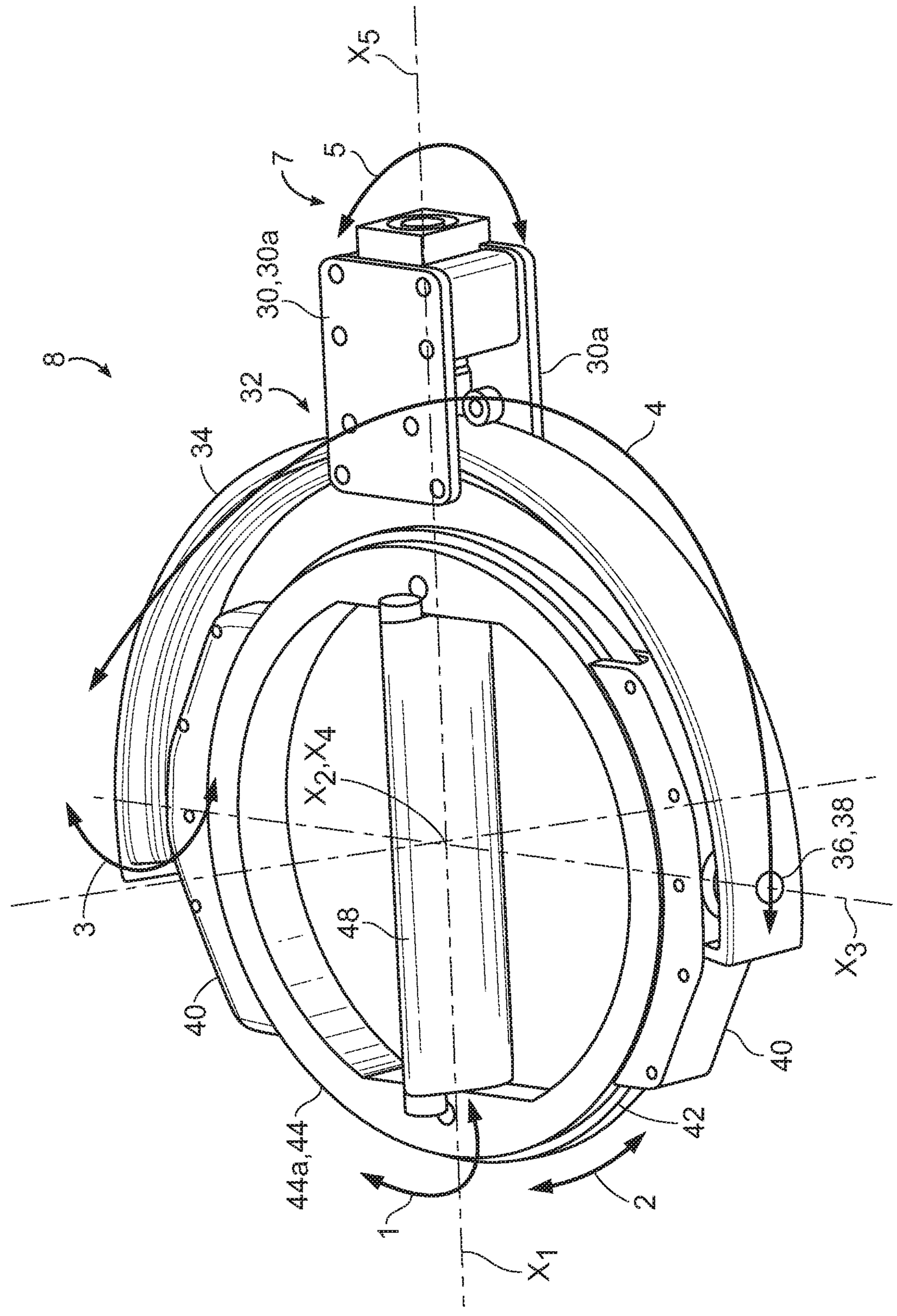


FIG. 4

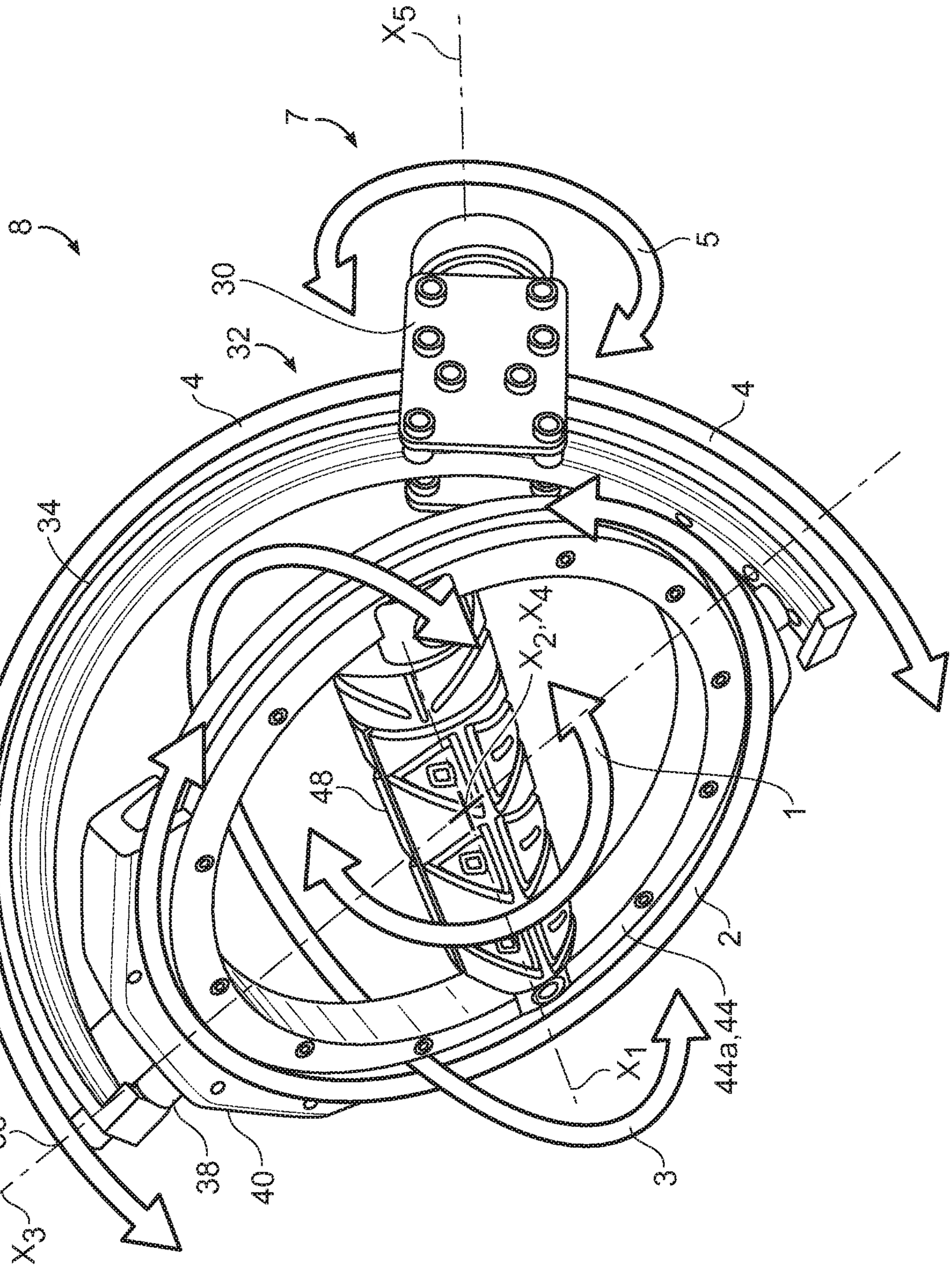
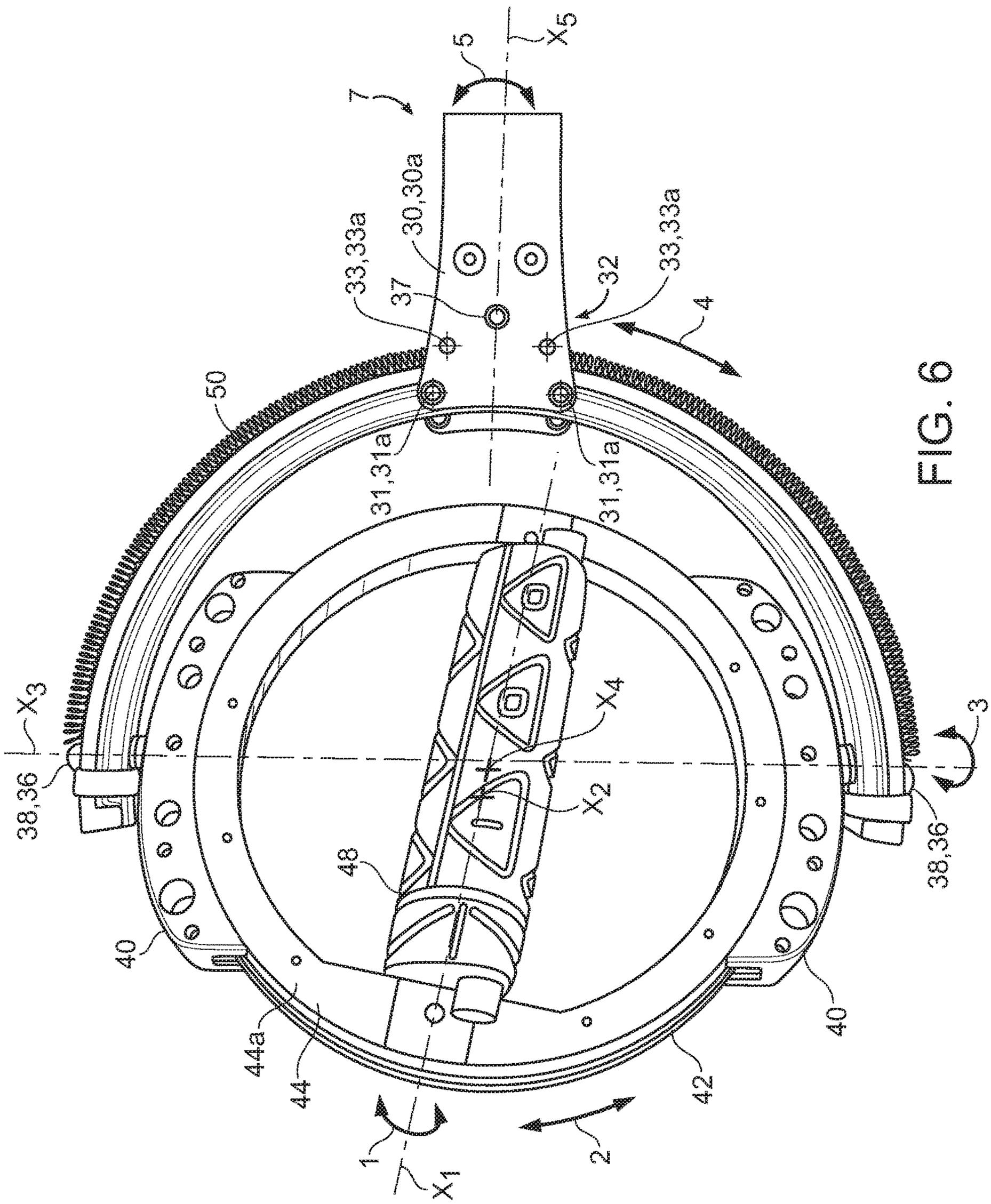


FIG. 5


7
5
X5
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50
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31,31a
X3
38,36
X4
X2
48
38,36
3
40
44a
44
42
40
1
2
X1

FIG. 6

EXERCISE DEVICE LIMB INTERFACE

RELATED APPLICATION(S)

This application claims the benefit of U.S. Provisional Application No. 62/580,177, filed on Nov. 1, 2017. The entire teachings of the above application(s) are incorporated herein by reference.

BACKGROUND

Handle or limb interfaces for exercise machines in the prior art have been deficient in comfortably and realistically exercising complex motions, such as exercising a throwing motion. Some prior interfaces have caused pain or discomfort to the user's hand, inability to complete a movement, or locking and/or flipping of joints.

SUMMARY

The present invention can provide a limb interface device for an exercise apparatus that can allow complex motions to be exercised without uncomfortable or undesirable positions of the limb interface occurring while being held by the user during exercise. The limb interface device can be attached to a computerized exercise apparatus such as in U.S. Pat. Nos. 5,755,645 and 9,861,856.

The limb interface device can include a handle member mounted within an inner frame member and can be rotatable about a first axis with a first joint, for gripping with one or two hands by a user. The first joint can be limited to about 40° or less rotation. At least one outer support member can support the inner frame member. The inner frame member can be rotatable about a second axis orthogonal to the first axis with a second joint. An outer arc member can support the at least one support member. The at least one support member can be rotatable about a third axis orthogonal to the second axis with a third joint. An arm member can support the outer arc member. The outer arc member can rotate about a fourth axis that is orthogonal to the third axis with a fourth joint. The fourth joint can allow rotation of about 180° or less rotation and is associated with a centering biasing arrangement for resiliently biasing the outer arc member towards a centered position when rotated. The arm member can also be rotatable about a fifth axis that is longitudinal to the arm member and orthogonal to the fourth axis with a fifth joint. The arm member for extending from the exercise apparatus.

In particular embodiments, the inner frame member can include a ring within which the handle member is mounted. The ring can be rotatably mounted between a pair of outer support members. The centering biasing arrangement can include a coil spring secured to and extending along an outer perimeter of the outer arc member for biasing the outer arc member. In some embodiments, the coil spring can be substituted by using a rubber bungee member or other similar mechanism. The outer arc member can slidably pass through the fourth joint in an arc. The outer arc member can comprise a semicircular ring that engages rollers positioned within the arm member. The handle member can be rotatably mounted about the first axis to an inner race of a bearing that is rotatable about the second axis within an outer race of the bearing. The pair of outer support members can be secured to and support the outer race of the bearing. In some embodiments, the arm member can be mounted to a movable arm of a computerized exercise device. In other embodiments, the arm member can be mounted to a cable of an exercise device.

The present invention can also provide a limb interface device having a handle member mounted within an inner frame member and can be rotatable about a first axis with a first joint, for gripping with one or two hands by a user. The first joint can be limited to about 180° or less rotation. At least one outer support member can support the inner frame member. The inner frame member can be rotatable about a second axis orthogonal to the first axis with a second joint. An outer arc member can support the at least one support member. The at least one support member can be rotatable about a third axis orthogonal to the second axis with a third joint. An arm member can support the outer arc member. The outer arc member can rotate about a fourth axis that is orthogonal to the third axis with a fourth joint. The fourth joint can allow rotation of about 180° or less rotation and be associated with a centering biasing arrangement for resiliently biasing the outer arc member towards a centered position when rotated.

In particular embodiments, the inner frame member can include a ring within which the handle member is mounted. The ring can be rotatably mounted between a pair of outer support members. The centering biasing arrangement can include a biasing member associated with the outer arc member for biasing the outer arc member. The outer arc member can slidably pass through the fourth joint in an arc.

The present invention can also provide a method of using a limb interface device for an exercise apparatus including gripping a handle member with one or two hands of the user. The handle member can be mounted within an inner frame member and be rotatable about a first axis with a first joint. The first joint can be limited to about 40° or less rotation. Rotation of the inner frame member can be allowed relative to at least one support member supporting the inner frame member. The inner frame member can be rotatable about a second axis orthogonal to the first axis with a second joint. Rotation of the at least one support member can be allowed relative to an outer arc member that supports the at least one support member. The at least one support member can be rotatable about a third axis orthogonal to the second axis with a third joint. Rotation of the outer arc member can be allowed relative to an arm member that supports the outer arc member. The outer arc member can be rotatable about a fourth axis that is orthogonal to the third axis with a fourth joint. The fourth joint can have rotation of about 180° or less rotation and is associated with a centering biasing arrangement for resiliently biasing the outer arc member towards a centered position when rotated. Rotation of the arm member can be allowed about a fifth axis that is longitudinal to the arm member and orthogonal to the fourth axis with a fifth joint. The arm member for extending from the exercise apparatus.

In particular embodiments, the inner frame member can include a ring within which the handle member is mounted. The ring can be rotatably mounted between a pair of outer support members. The centering biasing arrangement can include a coil spring secured to and extending along an outer perimeter of the outer arc member for biasing the outer arc member. In some embodiments, the coil spring can be substituted by using a rubber bungee member or other similar mechanism. The outer arc member can slidably pass through the fourth joint in an arc. The outer arc member can comprise a semicircular ring that engages rollers positioned within the arm member. The handle member can be rotatably mounted about the first axis to an inner race of a bearing that

is rotatable about the second axis within an outer race of the bearing. The pair of outer support members can be secured to and support the outer race of the bearing. In some embodiments, the arm member can be mounted to a movable arm of a computerized exercise device. In other embodiments, the arm member can be mounted to a cable of an exercise device. Further details of the present invention limb interface can be found in the attached description and drawings. Embodiments of the limb interface can have axes of rotation, such as axes X_1, X_2, X_3, X_4, and X_5. In some embodiments, axes X_2 and X_4 can coincide, and in other embodiments can be apart.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing will be apparent from the following more particular description of example embodiments, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating embodiments.

FIG. **1** is a perspective view of an exercise handle in the prior art.

FIG. **2** is a side schematic view of an exercise machine in the present invention.

FIG. **3** is a plan view of an embodiment of a limb interface device or handle assembly in the present invention.

FIG. **4** is a perspective view of a version of the limb interface device of FIG. **3**.

FIG. **5** is a perspective view of another version of the limb interface device of FIG. **3**.

FIG. **6** is a plan view of yet another version of the limb interface device of FIG. **3**.

DETAILED DESCRIPTION

Exercise handles in the prior art have been used with exercise machines for gripping by the user while performing exercises. Referring to FIG. **1**, in the prior art, exercise handle **100** can have a handle grip **102** that is rotatably mounted to a first handle member **106** and is rotatable about a first axis X_1 in the direction of arrows **104**. The first handle member **106** is rotatably mounted to a second handle member **110**, and is rotatable about a second axis X_2 in the direction of arrows **108**. The second handle member **110** is rotatably mounted to a third handle member **114** and is rotatable about a third axis X_3 in the direction of arrows **112**. The third handle member **114** is rotatably mounted to the desired exercise machine and is rotatable about a fourth axis X_4 in the direction of arrows **116**. Although the exercise handle **100** has four axes of rotation, when a user is exercising a complex motion such as a throwing motion, a problem known as gimbal lock typically occurs, adversely affecting the exercise.

Gimbal lock can occur when joints align in the exercise handle **100**, creating unintended contact with and interference with the user's arm or wrist. Gimbal lock can also cause elements or members of the exercise handle **100** to flip or swing, increasing inertia, causing unpleasant jerking sensations, or making contact with the user's wrist. The flipping due to a gimbal lock condition is known as a wrist singularity. At times, two of the axes of rotation of the exercise handle **100** can become parallel. When this condition occurs, the remaining axes of rotation of the exercise handle **100** attempts to rotate through a large angle as quickly as possible to maintain the wrist orientation, thus causing an unexpected flip of an outer member of the handle. This flipping from gimbal lock then forces other mechanical joints of the exercise handle **100** to adapt due to directional stress, adding torque within the joints, where energy is stored, until the gimbal lock is overcome, leading to a release of the torque that forces the joints to rotate at uncomfortable speeds. In many cases, the exercise movement becomes entirely disrupted and is difficult or impossible to complete without making unnatural biomechanical adjustments by the user. Gimbal lock is most problematic for multi-planar movements, especially at high velocities, such as during the performance of a sport specific movement, like simulating throwing a baseball.

FIGS. **2** and **3** show an embodiment of an exercise apparatus or device **10** having a limb interface device or exercise handle assembly **8**, in the present invention. The exercise device **10** can be a computerized exercise device such as in U.S. Pat. Nos. 5,755,645 and 9,861,856, the contents of which are incorporated herein by reference in their entirety. Exercise device **10** can include a base **12** with a body member **14** rotatably mounted thereto with a waist joint for side to side rotation in the direction of arrows **20**. A shoulder member **16** is rotatably mounted to the body member **14** with a shoulder joint for up-and-down rotation in the direction of arrows **22**. An elongate arm or arm member **18** can be mounted to the shoulder member **16** and can slidably extend and retract linearly in the direction of arrows **24**. Rotary motion of the shoulder member **16** can be braked or resisted by a computer controlled brake B**1**, rotary motion of body member **14** can be braked or resisted by a computer controlled brake B**2**, and linear motion of arm **18** can be braked or resisted by a computer controlled brake B**3**. Brakes B**1**, B**2** and B**3** can be magnetic particle brakes and controlled by a computer or controller **26**. A user when gripping the handle assembly **8** with hand **25** (or two hands **25**), can move the handle assembly **8** throughout a three-dimensional region of space **28** while experiencing resistance. The novel design of the handle assembly **8** in the present invention, which is further described below, allows the user to exercise complex motions such as a pitching motion without experiencing gimbal lock, so that portions of the handle assembly **8** do not interfere with the user's arm or wrist **25***a*, and flipping of elements or members of the handle assembly **8** does not occur.

The handle assembly **8** can include a gripping or a handle member **48** for gripping with one or two hands **25** of the user. The handle member **48** can be elongate and generally round or cylindrical in shape, and can include a textured or shaped surface for comfortable gripping with a hand **25**. The handle member **48** can be rotatably mounted within an inner annular or circular ring-shaped frame member **44** with a first handle rotatable joint **46**, and can be rotatable or movable about a first handle axis X_1 in a first handle direction indicated by arrows **1**. Rotation of the first handle joint **46** can be limited between rotational stops associated with the first joint **46** to be about 180° or less rotation, about 120° or less rotation, or about 60° or less rotation, such as about 40° rotation, which can prevent the circular frame **44** from rotating into and contacting the user's hand **25** during multiplanar or complex movements such as proprioceptive neuromuscular facilitation patterns, for example throwing. In some embodiments, the first joint **46** can be an adjustable joint in which the amount of rotation of the first joint **46** can be adjusted to less than 40°, or in other embodiments more than 40°, and can depend upon the size of circular frame **44**. The limited rotation of the first joint **46** can cause other joints in the handle assembly **8** to move to prevent gimbal lock and disruptive movements.

The inner circular ring-shaped frame member **44** can be mounted to or include an annular or circular ring-shaped bearing **45** having inner **45***a* and outer **45***b* races, which can rotate or move relative to each other due to rolling elements therebetween. Bearing **45** is preferably a slewing bearing, but can also be other types of bearings such as standard ball or roller bearings. Frame portion **44***a* of inner frame member **44** can be clamped or secured to the inner race **45***a* of bearing **45** and in some embodiments, can be formed in two pieces or halves. The handle member **48** can be rotatably mounted to the frame portion **44***a* with the first joint **46**. In some embodiments, the frame portion **44***a* can cover an inner diameter of inner race **45***a*. The outer race **45***b* of bearing **45** can be supported, secured or clamped by at least one outer support member or clamp **40**, for example two on opposite sides 180° apart from each other. As a result, the inner frame member **44** can rotate with the inner race **45***a* of bearing **45** relative to the outer race **45***b* and support clamps **40**, in a second handle direction indicated by arrows **2** about a second handle axis X_2 that is orthogonal or transverse relative to the first axis X_1, with a second handle rotatable joint **42**. The second joint **42** is formed by the moving or rotating joint or interface between the inner **45***a* and outer **45***b* races of bearing **45**, and can rotate in either direction as much as desired. In some embodiments, the two support clamps **40** can be replaced by single 180° arc shaped clamp. In other embodiments, the bearing **45** can be replaced by rollers mounted to the support clamp(s) **40** that can rotatably capture the inner circular ring-shaped frame member **44**.

The support clamp(s) **40** can have two radially outwardly extending pins, shafts or axles **36**, which can extend outwardly in opposite directions along a third handle axis X_3 into an outer arc shaped frame member **34** to form a third handle rotatable joint **38**. The third joint **38** rotatably or movably supports the support clamps **40** (which in turn supports the inner circular ring-shaped frame member **44** and handle member **48**), about axis X_3 that is orthogonal or transverse to axis X_2, and rotatable in a third handle direction indicated by arrows **3**. The third joint **38** can rotate or move in either direction as much as desired.

The outer arc shaped member **34** can be a semicircular ring or "C" shaped arc segment having about a 180° circular arc. The outer arc member **34** can have a central fourth handle axis X_4 orthogonal or transverse to axis X_3, that can in some embodiments coincide with axis X_2 and be spaced apart from axis X_3 (FIG. **3**), coincide with axis X_2 and intersect axis X_3 (FIGS. **4** and **5**), or be spaced apart from both axes X_2 and X_3 (FIG. **6**), depending upon the shape, size and spacing of the corresponding components. In some embodiments, when spaced apart, axes X_2, X_3 and X_4 can be considered close enough together to coincide or intersect.

An arm or bracket joint member **30** can rollably slidably support the outer arc member **34**. The arm member **30** can have two opposed faces or sides **30***a* which can support a series of low friction elements or rotatable rollers **31** and **33** therebetween, that movably, rollably or slidably capture the outer arc member **34** therein, forming a fourth handle joint **32** therebetween. The outer arc member **34** (with the support clamp(s) **40**, inner circular ring-shaped frame member **44** and handle member **48**) is slidably movable or rotatable about the fourth handle axis X_4 by a fourth handle rotatable joint **32** in a fourth handle direction indicated by arrows **4**. Two rollers **31** can be rotatable about axes **31***a* and can engage an arched recessed inner surface, step or shoulder **34***a* of the outer arc member **34**, and two rollers **33** can be rotatable about axes **33***a* for engaging the outer curved periphery or surface of outer arc member **34**, slidably or rollable trapping the outer arc member **34** between the rollers **31** and **33**. The opposite ends of the arc inner shoulder **34***a* can have raised radial shoulders or stops **34***b* defining the terminal ends that the outer arc member **34** can travel relative to or within arm member **30** in an arc, about 180° or less before the stops **34***b* engage rollers **31** or arm member **30** and prevent further travel. FIG. **5** depicts movement of the outer arc member **34** closer toward one stop **34***b*. The outer arc member **34** can sometimes travel or rotate about axis X_4 in a direction **4** parallel to handle **48** rotatable about axis X_1 in direction **1**, and/or in a direction parallel to the inner circular ring-shaped frame member **44** rotatable about axis X_2 in direction **2**, but is always orthogonal or transverse to rotation of inner circular ring-shaped frame member **44** and clamp(s) **40** about axis X_3 in direction **3**. This can allow the handle assembly **8** to remain adaptive to a user's movement even if some gimbal lock attempts to start to occur. Positioning the rollers **31** and **33** in the arm member **30** positions the weight of the rollers **31** and **33** closer to the end of the arm**18** of exercise device **10**, and further away from handle member **48**, to prevent or minimize additional flipping of elements or members of the handle assembly **8**, which can be caused by the weight of bearings positioned closer to the handle member **48** at a longer distance away from shoulder member **16**, which can generate higher velocities and momentum.

The arm member **30** can include or can be secured, coupled, connected or mounted to a wrist or fifth handle rotatable joint **7**, which in turn can be rotatably secured, coupled, connected or mounted to the arm **18** of the exercise device **10** for rotatably coupling the handle assembly **8** thereto. The wrist joint **7** can move or rotate about a fifth handle axis X_5 that is orthogonal or transverse to axes X_3 and X_4 in a fifth handle direction as indicated by arrows **5**. Axis X_5 can be aligned with axis X_A of the arm **18** of exercise device **10** to avoid forming offset moment forces relative to axis X_A of the arm **18** of exercise device **10**. This can allow precise measurement, control of the resistance, and proper exercise experience of the user exercising with the exercise device **10**. In some embodiments, the handle assembly **8** can be used with a cable exercise device, and axis X_5 can be aligned with a cable **35** (FIG. **3**).

Referring to FIG. **6**, in some embodiments, a resilient member such as a coil spring **50** can extend along the outer perimeter surface of the outer arc member **34** and be secured to opposite terminal ends. The midpoint or center of the length or arc of the spring **50** can be secured to the arm member **30** by a securement member or post **37**, thereby forming a centering biasing arrangement for biasing the outer arc member **34** towards a centered arc position relative to arm member **30**, when rotated away from center. This biasing towards the arc center helps move the fourth joint **32** during exercise toward center for preventing gimbal lock, flipping, or the joint **32** from getting stuck on one side, or end. In one embodiment, two opposing springs **50** of equal length and spring strength can be employed, each extending from opposite ends of outer arc member **34** and terminating, abutting or being secured to post **37**. Depending upon the situation, spring(s) **50** can use extension and/or compressive forces for centering. In some embodiments, the spring(s) **50** can be replaced with other resilient members such as rubber bands or bungee members, or other suitable biasing members or mechanisms such as gas piston springs, that can exert an arc centering bias.

The handle assembly **8** has multiple strategically positioned and configured rotational joints about axes, such that when gimbal lock would normally occur in prior art handles,

one or more of the other rotational joints engage or move to accommodate the user's natural movement, while also avoiding contact with the user's hand **25**. In use, when exercising a complex three-dimensional motion, the user's hand **25** can grip the handle member **48** of handle assembly **8**, and move the handle assembly **8** and arm member **18** of exercise device through the motion. As the handle member **48** initially rotates about axis X_1 in direction **1**, the joints around the other axes X_2, X_3, X_4 and X_5 may or may not be rotating. However, once handle member **48** reaches a rotational end point of its rotational limit, 180° or less such as a 40° rotational limit, one or more of the joints around axes X_2, X_3, X_4 and X_5 begin to move or rotate as needed to facilitate movement. This prevents handle member **48** from rotating too far with the first joint **46** before the other joints move, and avoids gimbal lock. Depending upon the rotation or orientation of the second and third joints **42** and **38**, the axis X_1 of handle member **48** can be aligned with axes X_3 or X_5, and can rotate in the same directions as the third or fifth joints **38** or **7**, in directions **3** and **5**. In addition, axis X_1 can be aligned with or parallel to axis X_4, where handle member **48** can rotate in a generally concentrically parallel arc with or relative to outer arc member **34**. Since handle member **48** can rotate in the same direction or parallel to these other joints, it can be seen how the limited rotational ability of handle member **48** when its own rotation is stopped, can activate rotation about other axes and joints. The third, fourth and fifth joints **38**, **32** and **7** have axes of rotation about axes X_3, X_4 and X_5 that are always orthogonal or transverse to each other. Axis X_2 is always orthogonal or transverse to X_3, but can be oriented to align with axis X_5. Although some of the joints and axes at times can be rotated into orientations to be aligned or redundant, the Applicant has found that having the five joints rotatable about axes X_1, X_2, X_3, X_4 and X_5 with rotation about axes X_1 and X_4 being limited to partial rotation, provide a configuration that allows exercise of natural complex three-dimensional arm and hand motions such as a pitching throwing motion in a smooth natural manner without gimbal lock. Faster complex exercises such as a pitching motion are inherently likely to experience gimbal lock in prior art exercise handles, while slow simple motions, such as a weight lifting press or curling motion, often do not. In some embodiments, the fifth joint about axis X_5 can be omitted, for example if handle assembly **8** is connected to a cable that can experience rotational twist, or if the exercise device itself has a rotational joint about axis X_5.

While example embodiments have been particularly shown and described, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the scope of the embodiments encompassed by the appended claims. In some embodiments, the length and/or width of the handle member mounted within an inner frame member can be increased to accommodate movements that involve two hands. This can be useful for sport or other functional movements including swinging a baseball bat or golf club.

What is claimed is:

1. A limb interface device for an exercise apparatus comprising:

a handle member mounted within an inner frame member and rotatable about a first axis with a first joint, for gripping with one or two hands by a user, the first joint being limited to 40° or less rotation;

at least one outer support member supporting the inner frame member, the inner frame member being rotatable about a second axis orthogonal to the first axis with a second joint;

an outer arc member supporting the at least one outer support member, the at least one outer support member being rotatable about a third axis orthogonal to the second axis with a third joint; and

an arm member supporting the outer arc member, the outer arc member being rotatable about a fourth axis that is orthogonal to the third axis with a fourth joint, the fourth joint allowing rotation of 180° or less rotation and associated with a centering biasing member interacting with the outer arc member for resiliently biasing the outer arc member towards a centered position when rotated, the arm member also being rotatable about a fifth axis that is longitudinal to the arm member and orthogonal to the fourth axis with a fifth joint, the arm member for extending from the exercise apparatus.

2. The limb interface device of claim **1** in which the inner frame member comprises a ring within which the handle member is mounted, wherein the at least one outer support member comprises a pair of outer support members, the ring is rotatably mounted between the pair of outer support members.

3. The limb interface device of claim **2** in which the handle member is rotatably mounted about the first axis to an inner race of a bearing that is rotatable about the second axis within an outer race of the bearing, the pair of outer support members being secured to and supporting the outer race of the bearing.

4. The limb interface device of claim **1** in which the centering biasing member comprises a coil spring secured to and extending along an outer perimeter of the outer arc member for biasing the outer arc member.

5. The limb interface device of claim **1** in which the outer arc member slidably passes through the fourth joint in an arc.

6. The limb interface device of claim **5** in which the outer arc member comprises a semicircular ring that engages rollers positioned within the arm member.

7. The limb interface device of claim **1** in which the exercise apparatus is computerized and the arm member is mounted to a movable arm of the exercise apparatus.

8. The limb interface device of claim **1** in which the arm member is mounted to a cable of the exercise apparatus.

9. A limb interface device for an exercise apparatus comprising:

a handle member mounted within an inner frame member and rotatable about a first axis with a first joint, for gripping with one or two hands by a user, the first joint being limited to 180° or less rotation;

at least one outer support member supporting the inner frame member, the inner frame member being rotatable about a second axis orthogonal to the first axis with a second joint;

an outer arc member supporting the at least one outer support member, the at least one outer support member being rotatable about a third axis orthogonal to the second axis with a third joint; and

an arm member supporting the outer arc member, the outer arc member being rotatable about a fourth axis that is orthogonal to the third axis with a fourth joint, the fourth joint allowing rotation of 180° or less rotation and associated with a centering biasing member

interacting with the outer arc member for resiliently biasing the outer arc member towards a centered position when rotated.

10. The limb interface device of claim **9** in which the inner frame member comprises a ring within which the handle member is mounted, wherein the at least one outer support member comprises a pair of outer support members, the ring is rotatably mounted between the pair of outer support members.

11. The limb interface device of claim **9** in which the centering biasing member is secured to the outer arc member for biasing the outer arc member.

12. The limb interface device of claim **9** in which the outer arc member slidably passes through the fourth joint in an arc.

13. A method of using a limb interface device for an exercise apparatus comprising:

gripping a handle member with one or two hands of a user, the handle member being mounted within an inner frame member and rotatable about a first axis with a first joint, the first joint being limited to 40° or less rotation;

allowing rotation of the inner frame member relative to at least one support member supporting the inner frame member, the inner frame member being rotatable about a second axis orthogonal to the first axis with a second joint;

allowing rotation of the at least one support member relative to an outer arc member supporting the at least one support member, the at least one support member being rotatable about a third axis orthogonal to the second axis with a third joint;

allowing rotation of the outer arc member relative to an arm member supporting the outer arc member, the outer arc member being rotatable about a fourth axis that is orthogonal to the third axis with a fourth joint, the fourth joint having rotation of 180° or less rotation and associated with a centering biasing member interacting with the outer arc member for resiliently biasing the outer arc member towards a centered position when rotated; and

allowing rotation of the arm member about a fifth axis that is longitudinal to the arm member and orthogonal to the fourth axis with a fifth joint, the arm member for extending from the exercise apparatus.

14. The method of claim **13** in which the inner frame member comprises a ring within which the handle member is mounted, wherein the at least one support member comprises a pair of support members, the ring is rotatably mounted between the pair of support members.

15. The method of claim **14** in which the handle member is rotatably mounted about the first axis to an inner race of a bearing that is rotatable about the second axis within an outer race of the bearing, the pair of support members being secured to and supporting the outer race of the bearing.

16. The method of claim **13** in which the outer arc member slidably passes through the fourth joint in an arc.

17. The method of claim **16** in which the outer arc member comprises a semicircular ring that engages rollers positioned within the arm member.

18. The method of claim **13** in which the centering biasing member comprises a coil spring secured to and extending along an outer perimeter of the outer arc member for biasing the outer arc member.

19. The method of claim **13** in which the exercise apparatus is computerized and the arm member is mounted to a movable arm of the exercise apparatus.

20. The method of claim **13** in which the arm member is mounted to a cable of the exercise apparatus.

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